Memo

WATER RIGHTS BUREAU
NEW APPROPRIATION'S PROGRAM

TO: Whom it may concern

FROM: Kim Overcast, New Appropriation's Program Manager

SUBJECT: Historic Consumptive Use Public Meetings

DATE: Tuesday, September 9, 2008

Hello,

In a New Appropriations change application proceeding, an applicant can only change the amount (acre-feet) equal to their historical consumptive use. Many applicants are finding it difficult to come up with that figure, because the people who actually operated the project are no longer available to explain the historical operation. So, several staff from the department have been working to find a method for coming up with a acre-foot volume that would be representative of irrigation in the area and typical of the historical consumptive use. The department is looking for a method to determine the amount that will be acceptable to the public and to the department.

We want to discuss the department's proposal with interested persons. The department will be holding 3 public meetings before anything is proposed through the Administrative Rule process. There will be a presentation by the department hydrologist explaining how the department came up with the proposed method. The meetings will be held as shown below.

City	Location	Address	Date	Time
Lewistown	Yogo Inn	211 East Main Street Lewistown MT	Tuesday, September 16, 2008	1:00 P.M.
Missoula	Broadway Inn	1609 W Broadway St Missoula MT	Friday September 19, 2008	10: 00 A.M.
Helena	Dept. of Health and Human Services Auditorium	111 North Sanders Helena MT (Enter in North Door)	Monday September 22, 2008	1:00 P.M.

We look forward to receiving your comments on the proposal. If you are unable to attend any of the meetings, please email questions and comments to kovercast@mt.gov.

The proposal is attached below.

DRAFT - DNRC Consumptive Use Review Document
September 8, 2008

The Montana Department of Natural Resources and Conservation (DNRC) Water Management Bureau (WMB) was tasked with producing historic consumptive use guidelines for DNRC rule making as it pertains to water rights change applications. The intent of the approach outlined below is to develop a reasonable method for estimating irrigation season historic consumptive use based on a comparison of historical hay production to obtainable yields. Due to the lack of historical water measurement and production records for individual producers, best available data were used. This document outlines the methods used and how the procedure might be applied. The majority of the data used herein are from the United States Department of Agriculture (USDA) National Agricultural Statistics Service (NASS), or generated using the USDA Natural Resources Conservation Service (NRCS) Irrigation Water Requirements (IWR) program.

Methods/Application

NASS Data

Alfalfa was chosen for this analysis due to the availability of production and water use data, and because alfalfa has the highest seasonal water demand of any commonly grown hay crop in Montana. The online NASS database was queried to acquire irrigated alfalfa yields (tons/acre) by county. County-wide alfalfa yields have been surveyed since 1964 and state wide yields since 1929. The Montana Agricultural Statistics Service indicated that approximately 80% of alfalfa producers (over 100 acres) report yield estimates each year and these reported yields are the basis for the statistical estimates (Peggy Stringer, personal communication).

The State of Montana recognizes historical water rights as any claimed right originating on or before July 1, 1973. To examine water use prior to 1973, over the long term, after 1973, and most recently, the NASS county data was broken into four time periods for analysis, 1964-1973, 1964-2006, 1974-2006, and 1997-2006 (Table 1). The data for each of these time periods were averaged to facilitate comparisons of pre- and post-1973 datasets. For purposes of determining historic consumptive use in a water right change proceeding, Montana law requires determination of pre-1973 water use. Therefore, the final DNRC methodology for estimating historic consumptive use is based on pre-1973 NASS data.

IWR

IWR was used to calculate both the total irrigation season alfalfa crop water requirement (inches) and that portion of the total crop water requirement (inches) that was supplied by irrigation. IWR water requirement estimates for alfalfa were made for 180 weather station locations throughout Montana (Figure 1; Table 2). Evapotranspiration (ET) was computed using the Blaney-Criddle (TR21) method, which is the only IWR methodology

applicable to Montana. The Blaney-Criddle method was compared with other evapotranspiration methods by United States Geological Survey, and their results indicate Blaney-Criddle produces acceptable predictability (Cruff and Thompson, 1967). The only counties not represented in this analysis were Daniels and Deer Lodge due to the lack of readily available weather data required to run the program. IWR estimates net monthly and seasonal crop irrigation requirements based on crop needs, effective precipitation, and the growing season length. It only estimates the amount of water that the crop needs for evapotranspiration; it does not estimate the amount of water that needs to be delivered to the field, which is the crop irrigation requirement divided by the irrigation efficiency.

The length of the growing season for each weather station was determined by the program based on 50 degrees Fahrenheit as the beginning growing season temperature, and 28 degrees Fahrenheit as the ending growing season temperature. Effective precipitation was calculated by IWR from the individual weather station data. To simulate center pivot sprinkler irrigation a net application of one inch for each irrigation was used, while a net irrigation application of four inches was used to simulate each flood irrigation. Carryover moisture at the end and the start of the season is generally set to one half of the net irrigation application in the western United States. However, to simulate drier end of season and start of season conditions, a carry-over moisture equal to 25% of the net irrigation application was used in this analysis. The humidity and wind conditions were assumed to be arid with moderate wind. The crop irrigation water requirements reported in this document are for a normal year as defined by IWR, which means there is a 50 percent chance during any given year that the precipitation will be higher or lower.

Obtainable Yield and Management Factor

Available literature suggests that alfalfa requires approximately 5-6 inches of water to produce one ton per acre of dried alfalfa hay and this response is linear. That is, each subsequent ton of hay produced requires another 5-6 inches of water (Smith et al., 1998; Bauder, 1977, 1978, 2001; Irmak, 2007; Hill, 2002; Hanson and Putnam, 2000). To be conservative, our analysis adopted a State wide value of 6 inches of water to produce each ton per acre of dried alfalfa. This value is similar to data from North Dakota, but slightly lower than the value reported for Kimberly, Idaho (Sammis, 1981; Shewmaker et. al., date unknown).

The estimated obtainable yield at each weather station was determined by dividing the total crop water requirement calculated with the IWR program, by 6 in/ton/acre. The county wide alfalfa hay yields from the NASS data were then divided by the estimated yields for the four analysis periods to obtain a management factor. The management factors give an estimate of what percent of the obtainable yield producers are typically obtaining in the field at a particular area. However, there are problems with calculating a management factor for a specific site when NASS data is a county-wide average.

The biggest problem is whether the elevation of the weather station used for the IWR computed yields is applicable to all of the irrigated land in the county. For counties where the elevation is relatively uniform, this does not present a problem. But in

Beaverhead County for instance, where there are large differences in elevation, problems occur. Some of these problems can be seen in Table 3, for higher elevation sites such as Wisdom and Jackson. The alfalfa hay yields at these higher elevation sites are likely well below the Beaverhead County average, as are the corresponding crop irrigation requirements. So when the NASS data for the county are divided by the relatively low obtainable yield for a high elevation site, a management factor of over 100 percent can result.

The approach we took to try and resolve this problem was to calculate a county-wide management factor that was most representative for the majority of the irrigated lands in that county. The first step in this analysis was to determine the most representative weather station for the county-wide NASS data. GIS data were used to determine the average elevation and the approximate centroid of irrigated land within each county (the GIS data did not indicate any irrigated land in Wibaux county). The data were then compared to elevation and coordinate data for the weather stations to determine the most representative station for each county. In counties with only one weather station that station was considered to be the most representative. Once the most representative weather station was chosen the methodology described above was used to find the management factor.

Multiple regression and climatic area approaches were also tested; however, the results still did not reduce management factors below 100 percent.

County Management Factor Application

It is envisioned that a water right change applicant could use two tables to determine location specific historic consumptive use for an entire irrigation season. The first table would be a list of county management factors based on pre-1973 NASS data. The second table would be flood and sprinkler irrigation water requirements for the 180 weather stations. Historic consumptive use for a specific location could then be estimated by multiplying the irrigation water requirement of the most representative weather station by the county management factor.

Example 1: Estimate irrigation season historic consumptive use for an acre of flood irrigation near Three Forks, MT.

County management factor for Gallatin County from Table 4 is 73.5 percent of the obtainable yield. The most representative weather station is Trident, and the calculated seasonal flood irrigation water requirement is 19.07 inches (Table 2).

0.735 * 19.07 inches = 14.02 inches

In this example the historic consumptive use for Three Forks based on management practices for Gallatin County are estimated to be 14.02 inches of water per acre or 1.17 acre-feet per acre. When applied in the context of DNRC water rights changes this would be a starting point for the applicant. An applicant who thought that the estimated volume

of water was too low to reflect historic conditions specific to their irrigation system could present evidence/proof, such as diversion records matched to hay-harvests, to argue for a higher amount.

References

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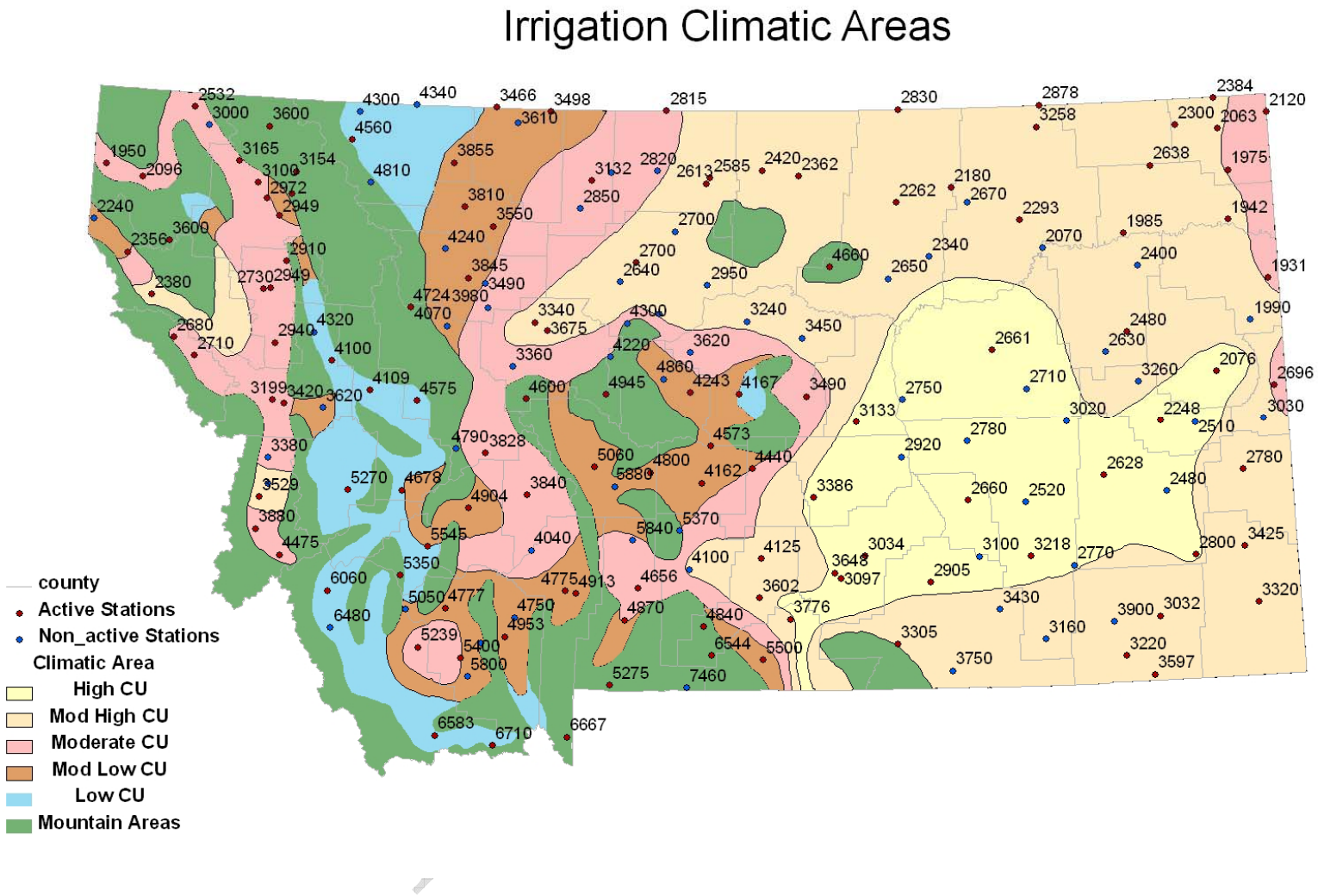

Figure 1. Location map of weather stations and their elevations in relation to Irrigation Climatic Areas.

Table 1. NASS county data broken into four time periods.

	Ag-Stats (County) Average Irr. Yield (tons/ac)			
	1964-1973	1964-2006	1973-2006	1997-2006
Beaverhead	2.54	3.14	3.30	3.52
Big Horn	2.45	3.26	3.48	3.90
Blaine	2.76	2.94	2.99	3.10
Broadwater	3.15	3.52	3.61	3.96
Carbon	2.84	3.17	3.26	3.45
Carter	1.74	2.32	2.48	2.45
Cascade	2.56	3.00	3.13	3.52
Chouteau	2.53	3.02	3.14	3.77
Custer	2.80	3.49	3.70	4.17
Dawson	3.21	3.49	3.59	4.07
Fallon	2.37	2.38	2.38	2.37
Fergus	1.88	2.40	2.53	2.63
Flathead	3.32	3.53	3.58	3.66
Gallatin	2.90	3.47	3.63	3.89
Garfield	2.21	2.49	2.57	2.34
Glacier	2.22	2.64	2.74	2.75
Golden Valley	2.49	2.57	2.61	2.57
Granite	2.64	2.68	2.67	2.95
Hill	2.66	2.87	2.94	2.97
Jefferson	2.30	2.81	2.94	3.06
Judith Basin	1.95	2.53	2.69	2.72
Lake	2.53	3.04	3.17	3.15
Lewis & Clark	2.40	2.99	3.15	3.18
Liberty	2.29	2.66	2.75	2.67
Lincoln	2.13	2.47	2.55	2.66
Madison	2.53	2.94	3.06	3.23
McCone	2.37	2.85	2.98	3.28
Meagher	2.13	2.52	2.61	2.91
Mineral	2.65	2.92	2.98	3.00
Missoula	2.94	2.88	2.86	2.94
Musselshell	2.60	2.96	3.05	2.92
Park	2.26	2.55	2.62	2.68
Petroleum	2.14	2.37	2.43	2.10
Phillips	2.62	2.62	2.62	2.63
Pondera	2.72	3.01	3.09	3.19
Powder River	1.90	2.32	2.44	2.63
Powell	2.31	2.61	2.68	3.07
Prairie	2.92	3.46	3.61	4.13
Ravalli	3.33	3.62	3.71	4.02
Richland	2.94	3.64	3.83	4.64
Roosevelt	2.45	3.23	3.42	3.93
Rosebud	2.43	3.23	3.44	3.70
Sanders	2.33	2.66	2.74	2.49
Sheridan	2.09	2.97	3.19	3.76
Silverbow	2.36	2.95	3.09	3.21
Stillwater	2.11	2.72	2.85	3.29
Sweet Grass	2.09	2.42	2.51	2.31
Teton	2.95	3.34	3.44	3.79
Toole	2.26	2.77	2.90	3.09
Treasure	2.85	3.77	4.01	4.89
Valley	2.90	3.23	3.34	3.75
Wheatland	1.92	2.32	2.42	2.24
Yellowstone	3.29	3.80	3.95	4.30
State wide average	**2.5**	**2.9**	**3.0**	**3.2**

Table 2. IWR data for seasonal alfalfa evapotranspiration.

County	Climate Station	Elevation	IWR Total Seasonal ET (in)	IWR Center Pivot Irrigation Seasonal ET (in)	IWR Flood Irrigation Seasonal ET (in)
Beaverhead	Dillon	5239	23.92	19.78	17.05
	Wisdom	6060	11.12	8.82	6.72
	Jackson	6480	12.12	9.83	7.73
	Lakeview	6710	13.49	10.02	7.52
	Lima	6583	18.76	15.23	12.72
Big Horn	Busby	3430	26.55	21.87	18.96
	Hardin	2905	33.45	28.88	26.01
	Hysham 25	3100	26.65	21.80	18.84
	Wyola	3750	25.95	20.84	17.79
	Yellowtail Dam	3305	36.97	29.83	26.12
Blaine	Chinook	2420	27.86	22.32	19.12
	Harlem	2362	28.18	23.05	19.99
Broadwater	Townsend	3840	25.24	20.77	17.93
	Trident	4040	27.29	22.14	19.07
Carbon	Joliet	3776	29.24	24.03	20.94
	Red Lodge	5500	22.89	17.44	14.28
Carter	Ekalaka	3425	28.14	21.83	18.38
	Ridgeway	3320	27.18	21.83	18.70
Cascade	Cascade 20	4600	20.16	15.67	12.83
	Cascade 5	3360	25.25	19.56	16.31
	Great Falls	3675	26.81	21.37	18.21
	Neihart	4945	19.80	14.01	10.73
	Sun River	3340	24.27	19.59	16.68
Chouteau	Big Sandy	2700	28.90	23.06	19.76
	Fort Benton	2640	29.05	23.51	20.32
	Geraldine	3130	28.12	21.95	18.55
	Iliad	2950	28.43	23.03	19.89
	Loma	2700	29.54	24.14	21.00
	Shonkin	4300	22.78	15.44	11.64
Custer	Miles City	2628	34.12	28.21	24.89
	Mizpah	2480	30.84	25.32	22.14
	Powderville	2800	32.20	26.38	23.09
Dawson	Glendive	2076	33.90	27.54	24.08
Fallon	Plevna	2780	29.87	24.07	20.79
Fergus	Denton	3620	22.26	16.97	13.87
	Grass Range	3490	26.88	20.60	17.16
	Lewistown	4167	23.10	17.25	13.96
	Roy	3450	27.28	21.50	18.23
	Winifred	3240	25.38	19.50	16.18
Flathead	Creston	2949	22.31	16.70	13.49
	Hungry Horse Dam	3160	24.21	16.95	13.18
	Kalispell	2972	22.73	18.10	15.21
	Olney	3165	19.10	14.31	11.37
	Polebridge	3600	15.39	11.87	9.36
	West Glacier	3154	21.85	15.83	12.48
	Whitefish	3100	23.18	17.55	14.32
Gallatin	Bozeman Exp Farm	4775	23.66	18.48	15.41
	Bozeman MT State	4913	26.26	20.16	16.78
	Hebgen Dam	6667	16.78	12.05	9.13

Garfield	Cohagen	2710	28.83	23.83	20.81
	Jordan	2661	30.52	25.07	21.91
	Mosby	2750	31.79	26.03	22.76
Glacier	Babb	4300	19.07	13.80	10.70
	Cut Bank	3855	22.33	17.50	14.54
	Del Bonita	4340	21.37	16.17	13.10
	East Glacier	4810	17.23	12.53	9.61
	St Mary	4560	21.43	15.64	12.37
Golden Valley	Ryegate	4440	23.87	19.09	16.16
Granite	Philipsburg Ranger Stn	5270	18.32	14.46	11.83
Hill	Fort Assinniboine	2613	29.50	23.93	20.72
	Guilford	2820	25.60	20.91	18.00
	Havre	2585	26.99	22.35	19.46
	Simpson	2815	25.50	21.00	18.15
Jefferson	Boulder	4904	22.64	18.50	15.78
Judith Basin	Moccasin Exp Stn	4243	23.71	17.83	14.51
	Raynesford	4220	23.78	17.86	14.54
	Stanford	4860	24.49	18.43	15.06
Lake	Bigfork	2910	26.26	19.33	15.67
	Polson	2949	27.51	22.10	18.95
	Polson Kerr Dam	2730	28.20	22.95	19.85
	St Ignatius	2940	26.68	21.18	18.01
Lewis & Clark	Augusta	4070	23.95	19.04	16.06
	Austin	4790	21.56	17.04	14.19
	Helena	3828	26.03	21.63	18.82
	Holter Dam	3490	30.80	25.34	22.18
	Lincoln Ranger Stn	4575	18.23	14.51	11.93
Liberty	Chester	3132	25.09	20.62	17.79
	Joplin	3300	24.55	20.29	17.53
	Tiber Dam	2850	28.88	24.29	32.41
Lincoln	Eureka Ranger Stn	2532	27.13	22.20	19.21
	Fortine	3000	22.46	17.70	14.77
	Libby Ranger Stn	2096	27.22	22.86	20.06
	Libby	3600	16.25	12.79	10.29
	Troy	1950	26.97	21.78	18.70
Madison	Alder	5800	19.99	15.85	13.13
	Ennis	4953	23.26	18.71	15.86
	Glen	5050	22.61	19.09	16.57
	Norris	4750	29.19	22.61	19.06
	Twin Bridges	4777	21.94	18.30	15.75
	Virginia City	5770	21.77	17.17	14.30
McCone	Brockway	2630	27.15	22.14	19.12
	Circle	2480	29.30	23.75	20.55
	Fort Peck Power Plnt	2070	32.50	26.79	23.54
	Vida	2400	29.34	23.30	19.93
Meagher	Lennep	5880	17.71	13.55	10.82
	Martinsdale	4800	21.34	16.71	13.83
	White Sulpher Spr	5060	22.30	17.92	15.12
Mineral	St Regis Ranger Stn	2680	23.36	19.26	16.54
	Superior	2710	28.31	23.57	20.64
Missoula	Lindbergh Lake	4320	20.94	16.48	13.65
	Missoula	3420	25.40	20.50	17.52
	Missoula WSO AP	3199	25.20	20.98	18.23
	Potomac	3620	18.85	15.60	13.18
	Seeley Lake Ranger Stn	4100	20.64	16.55	13.85
Musselshell	Melstone	2920	32.00	25.83	22.42

	Roundup	3386	31.17	25.50	22.26
Park	Cooke City	7460	16.43	10.64	7.36
	Gardiner	5275	27.39	23.77	21.22
	Livingston	4870	23.83	18.25	15.05
	Livingston FAA AP	4656	25.62	20.25	17.11
	Wilsall	5840	20.38	14.98	11.84
Petroleum	Flatwillow	3133	29.20	23.78	20.63
Phillips	Content	2340	28.39	23.00	19.86
	Malta 35	2650	27.10	21.76	18.63
	Malta 7	2262	28.73	23.10	19.88
	Port of Morgan	2830	26.42	21.44	18.44
	Saco	2180	26.39	21.56	18.61
	Zortman	4660	22.41	16.12	12.67
Pondera	Conrad	3550	22.87	18.40	15.57
	Valier	3810	24.88	19.77	16.73
Powder River	Biddle	3597	29.01	23.45	20.24
	Broadus	3032	29.63	24.56	21.52
	Moorhead	3220	30.47	25.22	22.12
	Sonnette	3900	24.86	19.89	16.89
Powell	Deer Lodge	4678	17.85	14.53	12.09
	Ovando	4109	16.86	13.77	11.41
Prairie	Mildred	2510	29.55	24.39	21.32
	Terry	2248	29.38	24.26	21.21
	Terry 21	3260	25.38	20.17	17.09
Ravalli	Darby	3880	25.00	20.52	17.68
	Hamilton	3529	25.55	21.45	18.75
	Stevensville	3380	24.19	20.67	18.16
	Sula	4475	17.39	13.67	11.09
	Western Ag Research	3600	25.11	21.25	18.63
Richland	Savage	1990	31.51	25.16	21.70
	Sidney	1931	30.29	24.06	20.63
Roosevelt	Bredette	2638	27.42	21.50	18.18
	Culbertson	1942	28.38	22.36	19.01
	Wolf Point	1985	31.62	25.63	22.29
Rosebud	Birney	3160	31.40	26.10	22.98
	Brandenberg	2770	30.54	25.38	22.32
	Colstrip	3218	30.40	24.87	21.69
	Forsythe	2520	32.61	26.73	23.42
	Ingomar	2780	29.74	24.65	21.61
	Rock Springs	3020	27.64	22.76	19.79
Sanders	Heron	2240	22.55	16.92	13.70
	Thompson Falls Power	2380	29.95	24.36	21.15
	Trout Cr Ranger Sta	2356	23.78	18.61	15.54
Sheridan	Medicine Lake	1975	29.03	23.14	19.82
	Plentywood	2063	27.97	22.15	18.86
	Raymond Border Sta	2384	26.71	20.64	17.26
	Redstone	2300	24.72	19.36	16.22
	Westby	2120	25.77	19.66	16.27
Silverbow	Butte FAA AP	5545	20.04	16.22	13.61
	Divide	5350	20.57	16.72	14.09
Stillwater	Columbus	3602	29.39	23.93	20.76
	Mystic Lake	6544	21.55	15.54	12.19
	Nye	4840	22.69	16.73	13.39
	Rapelje	4125	27.21	21.94	18.84
Sweet Grass	Big Timber	4100	28.06	22.25	18.97
	Melville	5370	19.45	14.50	11.51

Teton	Blackleaf	4240	21.12	16.28	13.33
	Choteau Airport	3845	26.67	21.83	18.88
	Fairfield	3980	25.72	20.58	17.53
	Gibson Dam	4724	20.16	15.22	12.23
Toole	Goldbutte	3498	22.91	17.83	14.79
	Sunburst	3610	25.61	20.24	17.11
	Sweetgrass	3466	26.18	19.80	16.32
Treasure	Hysham	2660	32.05	26.54	23.35
Valley	Glasgow WSO AP	2293	30.03	24.85	21.78
	Hinsdale	2670	30.42	23.79	20.23
	Opheim 10	2878	22.85	17.67	14.60
	Opheim 16	3258	23.15	18.19	15.18
Wheatland	Harlowton	4162	24.72	19.38	16.26
	Judith Gap	4573	20.28	15.36	12.37
Wibaux	Carlyle	3030	27.35	21.49	18.19
	Wibaux	2696	25.89	20.25	17.02
Yellowstone	Billings Water Plant	3097	33.17	27.70	24.53
	Billings WSO	3648	32.39	27.06	23.94
	Huntley Exp Station	3034	28.68	23.47	20.39
Averages			**25.38**	**20.25**	**17.26**

Table 3. Obtainable yield and management factor for all weather stations.

County	Climate Station	IWR Total Seasonal ET (in)	Inches Required per Ton Alfalfa	Obtainable Yield (tons/ac)	Management Factor - % of Obtainable Yield			
					1964-1973	1964-2006	1973-2006	1997-2006
Beaverhead	Dillon	23.92	6	3.99	63.7	78.8	82.8	88.3
	Wisdom	11.12	6	1.85	137.1	169.4	178.2	189.9
	Jackson	12.12	6	2.02	125.7	155.4	163.5	174.3
	Lakeview	13.49	6	2.25	113.0	139.6	146.9	156.6
	Lima	18.76	6	3.13	81.2	100.4	105.6	112.6
Big Horn	Busby	26.55	6	4.43	55.4	73.7	78.7	88.1
	Hardin	33.45	6	5.58	43.9	58.5	62.5	70.0
	Hysham 25	26.65	6	4.44	55.2	73.4	78.4	87.8
	Wyola	25.95	6	4.33	56.6	75.4	80.5	90.2
	Yellowtail Dam	36.97	6	6.16	39.8	52.9	56.5	63.3
Blaine	Chinook	27.86	6	4.64	59.4	63.3	64.3	66.8
	Harlem	28.18	6	4.70	58.8	62.6	63.6	66.0
Broadwater	Townsend	25.24	6	4.21	74.9	83.6	85.9	94.1
	Trident	27.29	6	4.55	69.3	77.4	79.5	87.1
Carbon	Joliet	29.24	6	4.87	58.3	65.0	66.8	70.8
	Red Lodge	22.89	6	3.82	74.4	83.0	85.3	90.4
Carter	Ekalaka	28.14	6	4.69	37.1	49.5	52.9	52.2
	Ridgeway	27.18	6	4.53	38.4	51.3	54.7	54.1
Cascade	Cascade 20	20.16	6	3.36	76.2	89.3	93.0	104.8
	Cascade 5	25.25	6	4.21	60.8	71.3	74.3	83.6
	Great Falls	26.81	6	4.47	57.3	67.1	70.0	78.8
	Neihart	19.80	6	3.30	77.6	90.9	94.7	106.7
	Sun River	24.27	6	4.05	63.3	74.2	77.3	87.0
Chouteau	Big Sandy	28.90	6	4.82	52.5	62.6	65.3	78.3
	Fort Benton	29.05	6	4.84	52.3	62.3	64.9	77.9
	Geraldine	28.12	6	4.69	54.0	64.4	67.1	80.4
	Iliad	28.43	6	4.74	53.4	63.7	66.4	79.6
	Loma	29.54	6	4.92	51.4	61.3	63.9	76.6
	Shonkin	22.78	6	3.80	66.6	79.4	82.8	99.3
Custer	Miles City	34.12	6	5.69	49.2	61.4	65.1	73.3
	Mizpah	30.84	6	5.14	54.5	67.9	72.0	81.1
	Powderville	32.20	6	5.37	52.2	65.0	68.9	77.7

Dawson	Glendive	33.90	6	5.65	56.8	61.8	63.6	72.0
Fallon	Plevna	29.87	6	4.98	47.6	47.7	47.8	47.6
Fergus	Denton	22.26	6	3.71	50.7	64.6	68.3	70.9
	Grass Range	26.88	6	4.48	42.0	53.5	56.5	58.7
	Lewistown	23.10	6	3.85	48.8	62.3	65.8	68.3
	Roy	27.28	6	4.55	41.3	52.7	55.7	57.8
	Winifred	25.38	6	4.23	44.4	56.7	59.9	62.2
Flathead	Creston	22.31	6	3.72	89.3	95.0	96.3	98.4
	Hungry Horse Dam	24.21	6	4.04	82.3	87.5	88.7	90.7
	Kalispell	22.73	6	3.79	87.6	93.2	94.5	96.6
	Olney	19.10	6	3.18	104.3	111.0	112.4	115.0
	Polebridge	15.39	6	2.57	129.4	137.7	139.5	142.7
	West Glacier	21.85	6	3.64	91.2	97.0	98.3	100.5
	Whitefish	23.18	6	3.86	85.9	91.4	92.7	94.7
Gallatin	Bozeman Exp Farm	23.66	6	3.94	73.5	88.0	92.1	98.6
	Bozeman MT State Univ	26.26	6	4.38	66.3	79.3	83.0	88.9
	Hebgen Dam	16.78	6	2.80	103.7	124.1	129.9	139.1
Garfield	Cohagen	28.83	6	4.81	46.0	51.8	53.5	48.8
	Jordan	30.52	6	5.09	43.4	49.0	50.6	46.1
	Mosby	31.79	6	5.30	41.7	47.0	48.6	44.2
Glacier	Babb	19.07	6	3.18	69.8	83.0	86.2	86.5
	Cut Bank	22.33	6	3.72	59.7	70.9	73.6	73.9
	Del Bonita	21.37	6	3.56	62.3	74.1	76.9	77.2
	East Glacier	17.23	6	2.87	77.3	91.9	95.4	95.8
	St Mary	21.43	6	3.57	62.2	73.9	76.7	77.0
Golden Valley	Ryegate	23.87	6	3.98	62.6	64.7	65.5	64.6
Granite	Philipsburg Ranger Stn	18.32	6	3.05	86.5	87.7	87.4	96.6
Hill	Fort Assinniboine	29.50	6	4.92	54.1	58.5	59.8	60.4
	Guilford	25.60	6	4.27	62.3	67.4	68.9	69.6
	Havre	26.99	6	4.50	59.1	63.9	65.3	66.0
	Simpson	25.50	6	4.25	62.6	67.6	69.1	69.9
Jefferson	Boulder	22.64	6	3.77	61.0	74.4	77.9	81.1
Judith Basin	Moccasin Exp Stn	23.71	6	3.95	49.3	64.0	68.0	68.8
	Raynesford	23.78	6	3.96	49.2	63.8	67.8	68.6
	Stanford	24.49	6	4.08	47.8	61.9	65.8	66.6
Lake	Bigfork	26.26	6	4.38	57.8	69.4	72.4	72.0
	Polson	27.51	6	4.59	55.2	66.2	69.2	68.7
	Polson Kerr Dam	28.20	6	4.70	53.8	64.6	67.5	67.0

	St Ignatius	26.68	6	4.45	56.9	68.3	71.3	70.8
Lewis & Clark	Augusta	23.95	6	3.99	60.1	75.0	79.0	79.7
	Austin	21.56	6	3.59	66.8	83.3	87.7	88.5
	Helena	26.03	6	4.34	55.3	69.0	72.7	73.3
	Holter Dam	30.80	6	5.13	46.8	58.3	61.4	61.9
	Lincoln Ranger Stn	18.23	6	3.04	79.0	98.5	103.8	104.7
Liberty	Chester	25.09	6	4.18	54.8	63.6	65.7	63.9
	Joplin	24.55	6	4.09	56.0	65.0	67.1	65.3
	Tiber Dam	28.88	6	4.81	47.6	55.2	57.1	55.5
Lincoln	Eureka Ranger Stn	27.13	6	4.52	47.1	54.7	56.3	58.8
	Fortine	22.46	6	3.74	56.9	66.1	68.0	71.1
	Libby Ranger Stn	27.22	6	4.54	47.0	54.5	56.1	58.6
	Libby	16.25	6	2.71	78.6	91.4	94.0	98.2
	Troy	26.97	6	4.50	47.4	55.0	56.7	59.2
Madison	Alder	19.99	6	3.33	75.9	88.3	91.9	96.9
	Ennis	23.26	6	3.88	65.3	75.9	79.0	83.3
	Glen	22.61	6	3.77	67.1	78.1	81.2	85.7
	Norris	29.19	6	4.87	52.0	60.5	62.9	66.4
	Twin Bridges	21.94	6	3.66	69.2	80.5	83.7	88.3
	Virginia City	21.77	6	3.63	69.7	81.1	84.4	89.0
McCone	Brockway	27.15	6	4.53	52.4	63.1	65.8	72.5
	Circle	29.30	6	4.88	48.5	58.4	61.0	67.2
	Fort Peck Power Plnt	32.50	6	5.42	43.8	52.7	55.0	60.6
	Vida	29.34	6	4.89	48.5	58.4	60.9	67.1
Meagher	Lennep	17.71	6	2.95	72.2	85.3	88.6	98.6
	Martinsdale	21.34	6	3.56	59.9	70.8	73.5	81.8
	White Sulpher Spr	22.30	6	3.72	57.3	67.8	70.4	78.3
Mineral	St Regis Ranger Stn	23.36	6	3.89	68.1	75.1	76.7	77.1
	Superior	28.31	6	4.72	56.2	61.9	63.3	63.6
Missoula	Lindbergh Lake	20.94	6	3.49	84.2	82.6	81.8	84.2
	Missoula	25.40	6	4.23	69.4	68.1	67.5	69.4
	Missoula WSO AP	25.20	6	4.20	70.0	68.7	68.0	70.0
	Potomac	18.85	6	3.14	93.6	91.8	90.9	93.6
	Seeley Lake Ranger Stn	20.64	6	3.44	85.5	83.8	83.0	85.5
Musselshell	Melstone	32.00	6	5.33	48.8	55.4	57.2	54.8
	Roundup	31.17	6	5.20	50.0	56.9	58.7	56.2
Park	Cooke City	16.43	6	2.74	82.5	93.0	95.8	97.9
	Gardiner	27.39	6	4.57	49.5	55.8	57.5	58.7

	Livingston	23.83	6	3.97	56.9	64.1	66.1	67.5
	Livingston FAA AP	25.62	6	4.27	52.9	59.6	61.4	62.8
	Wilsall	20.38	6	3.40	66.5	75.0	77.2	78.9
Petroleum	Flatwillow	29.20	6	4.87	44.0	48.7	50.0	43.2
Phillips	Content	28.39	6	4.73	55.4	55.3	55.3	55.6
	Malta 35	27.10	6	4.52	58.0	57.9	58.0	58.2
	Malta 7	28.73	6	4.79	54.7	54.6	54.7	54.9
	Port of Morgan	26.42	6	4.40	59.5	59.4	59.4	59.7
	Saco	26.39	6	4.40	59.6	59.5	59.5	59.8
	Zortman	22.41	6	3.74	70.1	70.0	70.1	70.4
Pondera	Conrad	22.87	6	3.81	71.4	79.1	81.0	83.7
	Valier	24.88	6	4.15	65.6	72.7	74.5	76.9
Powder River	Biddle	29.01	6	4.84	39.3	47.9	50.4	54.4
	Broadus	29.63	6	4.94	38.5	46.9	49.3	53.3
	Moorhead	30.47	6	5.08	37.4	45.6	48.0	51.8
	Sonnette	24.86	6	4.14	45.9	55.9	58.8	63.5
Powell	Deer Lodge	17.85	6	2.98	77.6	87.8	90.0	103.2
	Ovando	16.86	6	2.81	82.2	92.9	95.2	109.3
Prairie	Mildred	29.55	6	4.93	59.3	70.3	73.2	83.9
	Terry	29.38	6	4.90	59.6	70.7	73.6	84.3
	Terry 21	25.38	6	4.23	69.0	81.9	85.2	97.6
Ravalli	Darby	25.00	6	4.17	79.9	87.0	89.0	96.5
	Hamilton	25.55	6	4.26	78.2	85.1	87.1	94.4
	Stevensville	24.19	6	4.03	82.6	89.9	92.0	99.7
	Sula	17.39	6	2.90	114.9	125.0	128.0	138.7
	Western Ag Research	25.11	6	4.19	79.6	86.6	88.6	96.1
Richland	Savage	31.51	6	5.25	56.0	69.3	72.9	88.4
	Sidney	30.29	6	5.05	58.2	72.0	75.9	91.9
Roosevelt	Bredette	27.42	6	4.57	53.6	70.6	74.8	86.0
	Culbertson	28.38	6	4.73	51.8	68.2	72.3	83.1
	Wolf Point	31.62	6	5.27	46.5	61.3	64.9	74.6
Rosebud	Birney	31.40	6	5.23	46.4	61.7	65.8	70.7
	Brandenberg	30.54	6	5.09	47.7	63.5	67.7	72.7
	Colstrip	30.40	6	5.07	48.0	63.8	68.0	73.0
	Forsythe	32.61	6	5.44	44.7	59.4	63.4	68.1
	Ingomar	29.74	6	4.96	49.0	65.2	69.5	74.6
	Rock Springs	27.64	6	4.61	52.7	70.1	74.8	80.3
Sanders	Heron	22.55	6	3.76	62.0	70.9	72.9	66.3

	Thompson Falls Power	29.95	6	4.99	46.7	53.3	54.9	49.9
	Trout Cr Ranger Sta	23.78	6	3.96	58.8	67.2	69.1	62.8
Sheridan	Medicine Lake	29.03	6	4.84	43.2	61.3	66.0	77.7
	Plentywood	27.97	6	4.66	44.8	63.7	68.5	80.7
	Raymond Border Sta	26.71	6	4.45	46.9	66.7	71.7	84.5
	Redstone	24.72	6	4.12	50.7	72.0	77.5	91.3
	Westby	25.77	6	4.30	48.7	69.1	74.3	87.5
Silverbow	Butte FAA AP	20.04	6	3.34	70.7	88.2	92.6	96.1
	Divide	20.57	6	3.43	68.8	85.9	90.3	93.6
Stillwater	Columbus	29.39	6	4.90	43.1	55.5	58.2	67.2
	Mystic Lake	21.55	6	3.59	58.7	75.6	79.4	91.6
	Nye	22.69	6	3.78	55.8	71.8	75.4	87.0
	Rapelje	27.21	6	4.54	46.5	59.9	62.9	72.5
Sweet Grass	Big Timber	28.06	6	4.68	44.7	51.7	53.6	49.4
	Melville	19.45	6	3.24	64.5	74.6	77.4	71.3
Teton	Blackleaf	21.12	6	3.52	83.8	94.8	97.7	107.7
	Choteau Airport	26.67	6	4.45	66.4	75.1	77.4	85.3
	Fairfield	25.72	6	4.29	68.8	77.9	80.2	88.4
	Gibson Dam	20.16	6	3.36	87.8	99.3	102.3	112.8
Toole	Goldbutte	22.91	6	3.82	59.2	72.6	76.0	80.9
	Sunburst	25.61	6	4.27	52.9	64.9	68.0	72.4
	Sweetgrass	26.18	6	4.36	51.8	63.5	66.5	70.8
Treasure	Hysham	32.05	6	5.34	53.4	70.6	75.2	91.5
Valley	Glasgow WSO AP	30.03	6	5.01	57.9	64.5	66.6	74.9
	Hinsdale	30.42	6	5.07	57.2	63.7	65.8	74.0
	Opheim 10	22.85	6	3.81	76.1	84.8	87.6	98.5
	Opheim 16	23.15	6	3.86	75.2	83.7	86.4	97.2
Wheatland	Harlowton	24.72	6	4.12	46.6	56.3	58.7	54.4
	Judith Gap	20.28	6	3.38	56.8	68.7	71.5	66.3
Wibaux	Carlyle	27.35	6	4.56	54.6	54.3	54.5	57.9
	Wibaux	25.89	6	4.32	57.6	57.4	57.5	61.2
Yellowstone	Billings Water Plant	33.17	6	5.53	59.5	68.7	71.4	77.8
	Billings WSO	32.39	6	5.40	60.9	70.4	73.1	79.7
	Huntley Exp Station	28.68	6	4.78	68.8	79.5	82.6	90.0
Averages		**25.4**		**4.2**	**61.9**	**72.2**	**74.9**	**79.7**

Table 4. County management factors based on most representative weather station.

County	Mean Elevation Irrigated Lands	Mean Latitude	Mean Longitude	Obtainable Yield	County Ag-stats 1964-1973 (ton/acre)	Management Factor 1964-1973
Beaverhead	5710	45.24	-112.66	4.0	2.54	63.7
Big Horn	3142	45.66	-107.59	4.4	2.45	55.4
Blaine	2512	48.54	-108.97	4.7	2.76	58.7
Broadwater	4051	46.24	-111.49	4.6	3.15	69.2
Carbon	4198	45.39	-108.99	4.9	2.84	58.3
Carter	3362	45.65	-104.40	4.5	1.74	38.4
Cascade	3651	47.37	-111.40	4.5	2.56	57.3
Chouteau	2791	47.88	-110.32	4.8	2.53	52.5
Custer	2447	46.43	-105.83	5.1	2.80	54.5
Dawson	2122	47.23	-104.87	5.7	3.21	56.8
Fallon	2818	46.42	-104.47	5.0	2.37	47.6
Fergus	3969	47.11	-109.56	3.9	1.88	48.8
Flathead	3008	48.22	-114.23	3.8	3.32	87.6
Gallatin	4648	45.81	-111.24	3.9	2.90	73.5
Garfield	2385	47.24	-106.94	5.1	2.21	43.4
Glacier	3910	48.77	-112.62	3.7	2.22	59.7
Golden Valley	3818	46.31	-109.14	4.0	2.49	62.6
Granite	4694	46.47	-113.28	3.1	2.64	86.5
Hill	2693	48.63	-110.17	4.9	2.66	54.1
Jefferson	4553	45.90	-112.00	3.8	2.30	61.0
Judith Basin	4264	47.11	-110.17	4.0	1.95	49.3
Lake	3027	47.49	-114.14	4.6	2.53	55.0
Lewis & Clark	4008	47.37	-111.40	4.0	2.40	60.1
Liberty	3070	48.56	-111.04	4.2	2.29	54.8
Lincoln	2752	48.38	-115.41	4.5	2.13	47.1
Madison	4992	45.46	-112.24	3.9	2.53	65.2
McCone	2109	47.60	-105.60	5.4	2.37	43.7
Meagher	5133	46.54	-110.97	3.7	2.13	57.3
Mineral	2932	47.14	-114.82	4.7	2.65	56.1
Missoula	3500	46.88	-114.06	4.2	2.94	69.5
Musselshell	3549	46.50	-108.42	5.2	2.60	50.0
Park	5081	45.71	-110.46	4.0	2.26	56.9
Petroleum	2883	46.97	-108.21	4.9	2.14	44.0
Phillips	2273	48.37	-107.88	4.8	2.62	54.7
Pondera	3674	48.30	-112.15	3.8	2.72	71.4
Powder River	3083	45.56	-105.79	4.9	1.90	38.5
Powell	4674	46.60	-112.85	3.0	2.31	77.6
Prairie	2260	46.81	-105.29	4.9	2.92	59.6
Ravalli	3697	46.39	-114.12	4.2	3.33	79.5
Richland	1968	47.78	-104.46	5.3	2.94	56.0
Roosevelt	1981	48.31	-105.01	5.3	2.45	46.5
Rosebud	2647	46.28	-106.59	5.1	2.43	47.7
Sanders	2854	47.63	-115.37	4.0	2.33	58.8
Sheridan	2027	48.70	-104.48	4.7	2.09	44.8
Silverbow	5389	45.92	-112.67	3.4	2.36	68.8
Stillwater	4054	45.83	-109.07	4.5	2.11	46.5
Sweet Grass	4638	45.86	-109.91	4.7	2.09	44.7
Teton	3933	47.91	-112.19	4.3	2.95	68.8
Toole	3434	48.71	-111.78	4.4	2.26	51.8
Treasure	2650	46.28	-107.27	5.3	2.85	53.4
Valley	2162	48.16	-106.59	5.0	2.90	57.9
Wheatland	4477	46.44	-109.85	4.1	1.92	46.6
Yellowstone	3096	45.82	-108.46	5.5	3.29	59.5